Single Pass Polarimetric SAR Interferometry

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ABSTRACT

During the past ten years, the NASA/JPL AIRSAR system has produced polarimetric and interferometric SAR data. SAR polarimetry is useful for characterizing scattering mechanisms while SAR interferometry yields high resolution topographic maps. For bare surfaces, the interferometric SAR topography represents true ground height. However, the radar height is biased by the volume scattering contribution from tree canopies for vegetated areas. Recently, Cloude and Papathanassiou developed a new radar technique called polarimetric SAR interferometry [1]. This technique can produce a radar topographic map corresponding to a particular scattering mechanism. In this way, both true ground height and tree height may be derived.

The NASA/JPL AIRSAR will be upgraded to collect the C-band polarimetric SAR interferometric data in May, 1998. In this talk, the hardware modifications required for this upgrade will be presented. Since the data will be collected in the single pass interferometric mode, one can study various combinations of interferometric/polarimetric data without suffering temporal decorrelation. Both theoretical and preliminary test results will be discussed.

SINGLE PASS POLARIMETRIC SAR INTERFEROMETRY

In this section, we present the polarimetric SAR interferometry formulation following [1]. The conventional interferometric SAR, as implemented in the NASA/JPL TOPSAR system, produces three major products: two SAR images (upper and lower antennas) and their complex cross correlation that produces an accurate DEM (Digital Elevation Model). Using a coherency matrix J, this interferometric operation can be written as

$$J = \left\langle \begin{bmatrix} s_u \\ s_l \end{bmatrix} \begin{bmatrix} s_u^* & s_l^* \end{bmatrix} \right\rangle = \left\langle \begin{bmatrix} s_u s_u^* & s_u s_l^* \\ s_l s_u^* & s_l s_l^* \end{bmatrix} \right\rangle \quad (1)$$

where s is the complex scattering coefficient. The diagonal components of the matrix represents the upper and lower antenna SAR images. The off-diagonal components represent cross-correlation from which interferometric height maps are derived.

The polarimetric scattering vector $\vec{k}$ in the backscattering direction is given by

$$\vec{k} = \begin{bmatrix} s_{hh} \\ s_{hv} \\ s_{vv} \end{bmatrix} \quad (2)$$

where we use the fact that $s_{hv} = s_{vh}$ in the backscattering direction. Other combinations of scattering coefficients can also be used for polarimetric SAR interferometry. Using the Pauli matrices, the polarimetric scattering vector can also be written as

$$\vec{k} = \begin{bmatrix} s_{hh} + s_{vv} \\ s_{vv} - s_{hh} \\ 2s_{hv} \end{bmatrix}. \quad (3)$$

Using the polarimetric scattering vector, one can form a polarimetric coherency matrix [1] as

$$T = \left\langle \begin{bmatrix} \vec{k}_u \\ \vec{k}_l \end{bmatrix} \begin{bmatrix} \vec{k}_u^* & \vec{k}_l^* \end{bmatrix} \right\rangle = \left\langle \begin{matrix} \vec{k}_u \vec{k}_u^* & \vec{k}_u \vec{k}_l^* \\ \vec{k}_l \vec{k}_u^* & \vec{k}_l \vec{k}_l^* \end{matrix} \right\rangle. \quad (4)$$

From the matrix elements in (4), one can form various polarimetric and interferometric pairs. Notice that an interferometric height can be derived from a particular pair corresponding to a certain scattering mechanism [2]. This concept can be applied to the canopy height estimation.

NASA/JPL AIRSAR IMPLEMENTATION

Note that the interferometric correlation γ_i can be written as

$$\gamma_i = \gamma_n \gamma_g \gamma_t \tag{5}$$

where the subscripts n, g, and t denote noise, geometric, and temporal decorrelations, respectively. Hence, single pass interferometry is much more desirable for polarimetric SAR interferometry since temporal decorrelation can be eliminated.

In order to collect AIRSAR data in the polarimetric SAR interferometric mode, the AIRSAR system must collect polarimetric data for both upper and lower antennas. Currently, the AIRSAR C-band interferometric antenna is vertically polarized. In order to implement polarimetric SAR interferometry, we had to construct polarimetric SAR antennas. The polarimetric antenna baseline is 2.5 m to be operated as an interferometric SAR, simultaneously. In addition, the required PRF must be doubled to minimize azimuth ambiguity noise. To implement this, the associated power supply must be changed to accommodate the required power consumption. High power switches have been added to perform this mode.

The AIRSAR swath is limited by its data transfer rate to the data recorder for the 40 MHz bandwidth mode. The 40 MHz bandwidth mode is preferable since more pixels can be averaged for higher DEM accuracy when compared with the 20 MHz bandwidth case. Since PRF must be doubled for the polarimetric SAR interferometric mode, the swath will be ½ of the conventional TOPSAR swath.

Even though a C-band radar signal may not penetrate the canopy layers as much as the L-band signal does, we chose to implement C-band polarimetric SAR interferometry since the AIRSAR C-band interferometric system has a sufficient baseline length for high accuracy DEM generation. This AIRSAR upgrade will be implemented during May, 1998.

Two major results will be verified.

- Optimum polarization state for maximum interferometric correlation
- Tree height estimation using various combinations of polarimetric SAR interferometric pairs

First, we will collect data for flat bare surfaces to study the optimum polarization state for maximum interferometric correlation. In addition, using these data, we also verify the correct implementation of this AIRSAR mode. Then, we will collect data over forestry areas to investigate the usefulness of polarimetric SAR interferometry for tree height estimation [3]. We hope to present the first single pass polarimetric SAR interferometry data.

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